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ADP014956

TITLE: Diffuse Dielectric Barrier Discharges in Nitrogen-Containing Gas Mixture

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TITLE: International Conference on Phenomena in Ionized Gases [26th] Held in Greifswald, Germany on 15-20 July 2003. Proceedings, Volume 4

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Diffuse dielectric barrier discharges in nitrogen-containing gas mixtures

R. Brandenburg[1], H.-E. Wagner[1], P. Michel[1], D. Trunec[2], P. Stahel[2]
[1] University of Greifswald, Institute of Physics, Domstrasse 10 a, 17489 Greifswald, Germany
[2] Department of Physical Electronics, Masaryk University, Kotlarska 2, 61137 Brno, Czech Republic

Diffuse dielectric barrier discharges are investigated in mixtures of nitrogen with several noble gasses (He, Ne, Ar). The results show that the discharge remains in the diffuse mode at relatively high content of the noble gases, which is contrary to the admixture of oxygen to nitrogen.

1. Introduction

Under special conditions dielectric barrier discharges (or barrier discharges, BD) can be operated in a diffuse mode, often called homogeneous mode or atmospheric pressure glow discharge (APGD). The diffuse BD in helium, nitrogen and neon has been intensively investigated by plasma diagnostics and numerical modelling [1 - 5]. The decisive criterion for the generation of a diffuse BD is the presence of charge carriers at a low electric field, i.e. a memory effect responsible for the production of primary electrons below breakdown voltage, otherwise microdischarges are formed. Several processes for this has been discussed as Penning ionisation due to metastable collisions [3] or electron desorption from the dielectric surface [4]. It was found out that the diffuse BD in nitrogen is a Townsend-like discharge, while the helium respectively neon diffuse BD is characterised by the formation of a cathode fall. For the case of diffuse BD in N_2 systematic measurements have shown that already oxygen admixtures of some hundreds of ppm lead to the generation of the usual filamentary mode. On the other hand diffuse BD could be generated in mixtures of nitrogen and argon with up to 70 % of argon content [6]. In this contribution we report the experimental study of diffuse BD in mixtures of nitrogen with the noble gases argon, helium or neon. The discharge voltage and current are measured and spatio-temporally resolved optical emission spectroscopy is performed. The aim of this work is the investigation of the transition between the two different types of diffuse BD and the selection of the conditions leading to the generation of either the Townsend-like or the glow-like form. By understanding the transition it might be possible to learn more about the elementary processes leading to a diffuse BD instead of a filamentary one.

2. Experimental technique

The BD is generated in flowing gas-mixtures between two semi-spherical electrodes covered by glass (1.5 mm thick), mounted with a gap distance of 1.4 mm. These special electrodes are usually used for the investigation of single microdischarges in the filamentary form [7]. The applied sinusoidal voltage (frequency f = 6.5 kHz) and the total discharge current are recorded with an oscilloscope (Tektronix TDS 380), the optical emission spectrum is investigated with a monochromator (Jobin Yvon Triax 320) and spatio-temporally resolved emission spectroscopy can be performed with the modificated set-up for cross-correlation spectroscopy [7].

3. Experimental results and discussion

The discharge behaviour representative for all gas mixtures under investigation is shown in fig. 1 for the helium-nitrogen mixtures. The burning voltage (i.e. the minimum voltage needed to sustain the diffuse discharge after first ignition) and the transition voltage (i.e. the voltage needed to cause the formation of microdischarges) are shown as a function of the gas composition. To distinguish between the discharge modes current oscillograms as shown in fig. 2 are used.

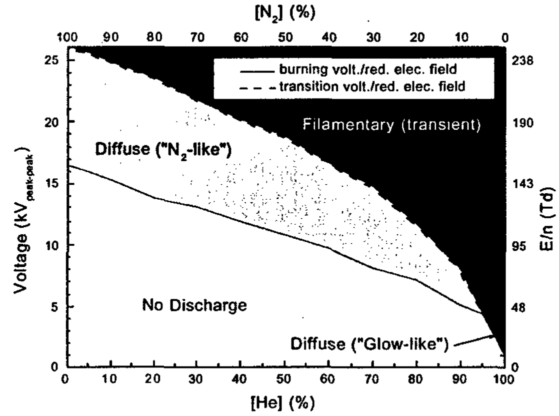

Figure 1: Burning and transition voltages in He-N_2-BDs (applied sinusoidal voltage with frequency f = 6.5 kHz)

Remarkably high content of the noble gases (up to 80 %) can be admixed to nitrogen without changing the diffuse nature of the discharge (see fig. 2b), if the applied voltage is chosen properly. Both threshold voltages decrease with the noble gas content and the interval for diffuse BD formation narrows. For almost pure helium/ neon the "Glow-like" type of barrier discharge is generated like in [1], while in pure argon a filamentary discharge is observed (see fig. 2a). The transition to the filamentary mode begins with the occurrence of regular oscillations in the discharge current (fig. 2c).

The luminosity distributions of diffuse BD in the mixtures of noble gas and nitrogen have their maximum nearby the anode (see fig. 3). This additionally proves that a Townsend-like discharge as in the case of pure nitrogen is formed. The oscillations described above are also present

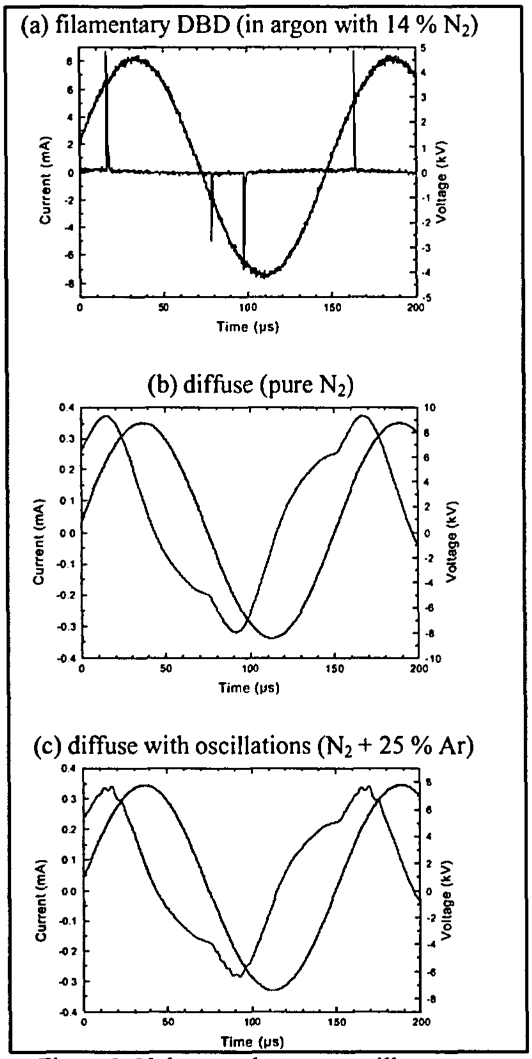

Figure 2: Voltage and current oscillograms

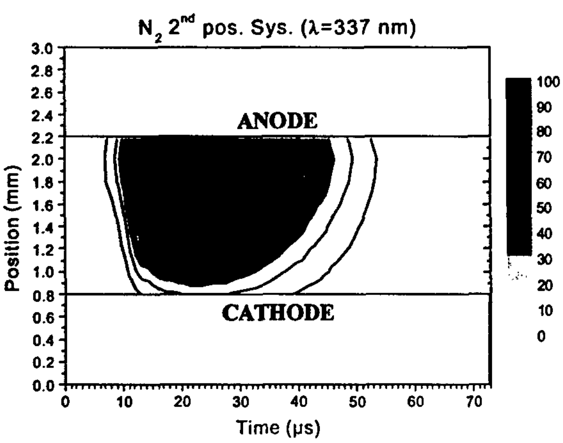

Figure 3: Results of spatio-temporally res. OES. 2nd positive system of N_2 (0-0 transition at 337 nm), conditions as in fig. 2c (Ar + 25 % N_2)

in the discharge luminosity of the second positive system of nitrogen (fig. 3) as well as of excited atomic argon. Both signals follows the discharge current in time. Furthermore the γ-spectrum of NO is observed in the spectra. But this signal is delayed about 25 μs against current and other intensities. The NO-signal is mainly caused by excitation via metastable $N_2(A)$ molecules. In contrast $N_2(C)$ and Ar^* excitation are initiated by electrons. One can conclude, that the oscillations describe an instability of the diffuse BD finally leading to the microdischarge formation.

The physical behaviour of the presented results is rather complex and not understood in detail up until now in atmospheric pressure discharges. The interpretation includes a multitude of processes. Some important are summarized in the following: The values of the first Townsend ionisation coefficient α are greater for noble gases than for N_2, resulting in the decrease of the threshold voltages in noble gas / nitrogen mixtures (comp. figure 1). Furthermore, in such discharges metastables of nitrogen and noble gases are formed. Via different Penning ionisation processes these metastables form effectively molecular nitrogen ions (N_2^+, N_4^+), affecting to the diffuse discharge mode.

4. Conclusion

Electric and spectroscopic diagnostics confirms that the admixture of noble gases argon, neon and helium to a diffuse, Townsend-like BD in nitrogen does not change the nature of the discharge significantly. A detailed interpretation of the results remains to future investigations.

5. Acknowledgements

The work was supported by Deutsche Forschungsgemeinschaft, SFB 198, "Kinetics of partially ionised plasmas".

6. References

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